Inexact Iterated FDM for cable-nets

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AAG2018
Advances in Architectural Geometry 2018
Chalmers University of Technology
Gothenburg, Sweden
22-25 September 2018

Topic description/ Abstract

Inexact Iterated FDM is an extension of the force density algorithm, originally used for form finding and internal force evaluation of tensile structures. The method is an improved version of an iterative algorithm operating on the force densities in order to attain target lengths and forces of cable-net bars. Improvements are aimed to be made in two segments. First, acceleration of the computation by relaxing the accuracy of the procedure in each iteration step maintaining it high enough not to compromise the convergence. Second, greater flexibility by introducing unstrained length constraint in addition to force and length constraints from initial set up of the algorithm.
Set of constraints allows user to manually influence the appearance of the final solution and enables further integration of the method into the interactive environment for form finding. The proposed algorithm is adjusted to COMPAS framework for "computational research and collaboration in architecture, structures and digital fabrication" and can be used in Rhinoceros.

Method

"Mixed formulation" based method, consists of the force density method that is iteratively used by recalculating force density coefficients in each step and conjugate gradients are used to solve the system of linear equations. The goal of the method is to reduce the number of iterations, and consequently the time, by optimizing in each iteration step, accuracy for solving the system of linear equations. In that way, inspired by Inexact Newton method, procedure provides the balance between the accuracy of the solutions of linear systems and the amount of computations done in single step of the iteration. Extension of the method enables assignment of unstrained lengths without introducing Lagrange multipliers, in addition to force and length constraints.

Results

Extensive numerical experiments show that the proposed method is almost always efficient and robust, although there are cases in which the efficiency strongly depends on constants in the proposed termination rule. The proposed rule for relaxation of accuracy is not the only one possible, so there still exist areas for further research and development.

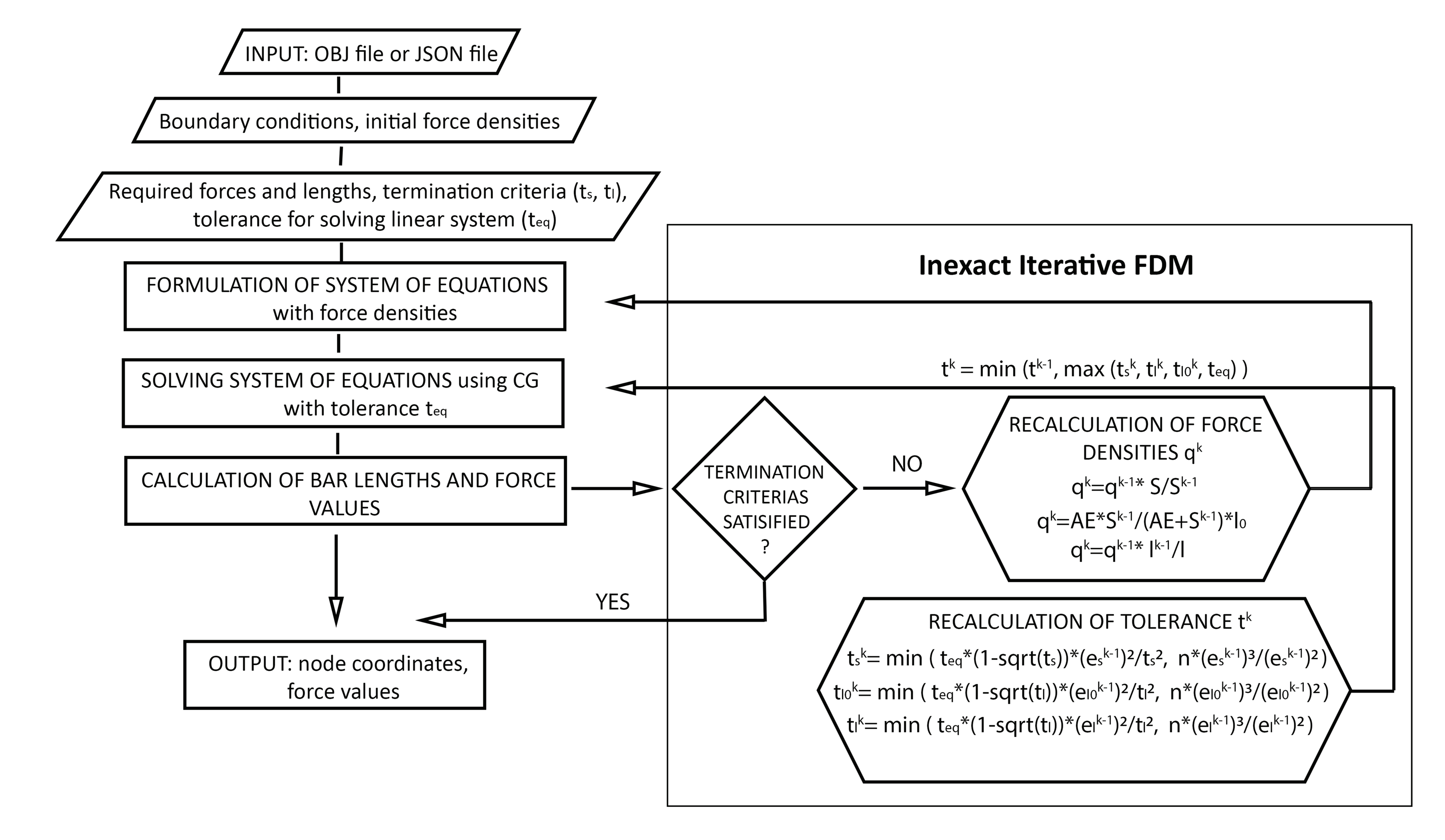
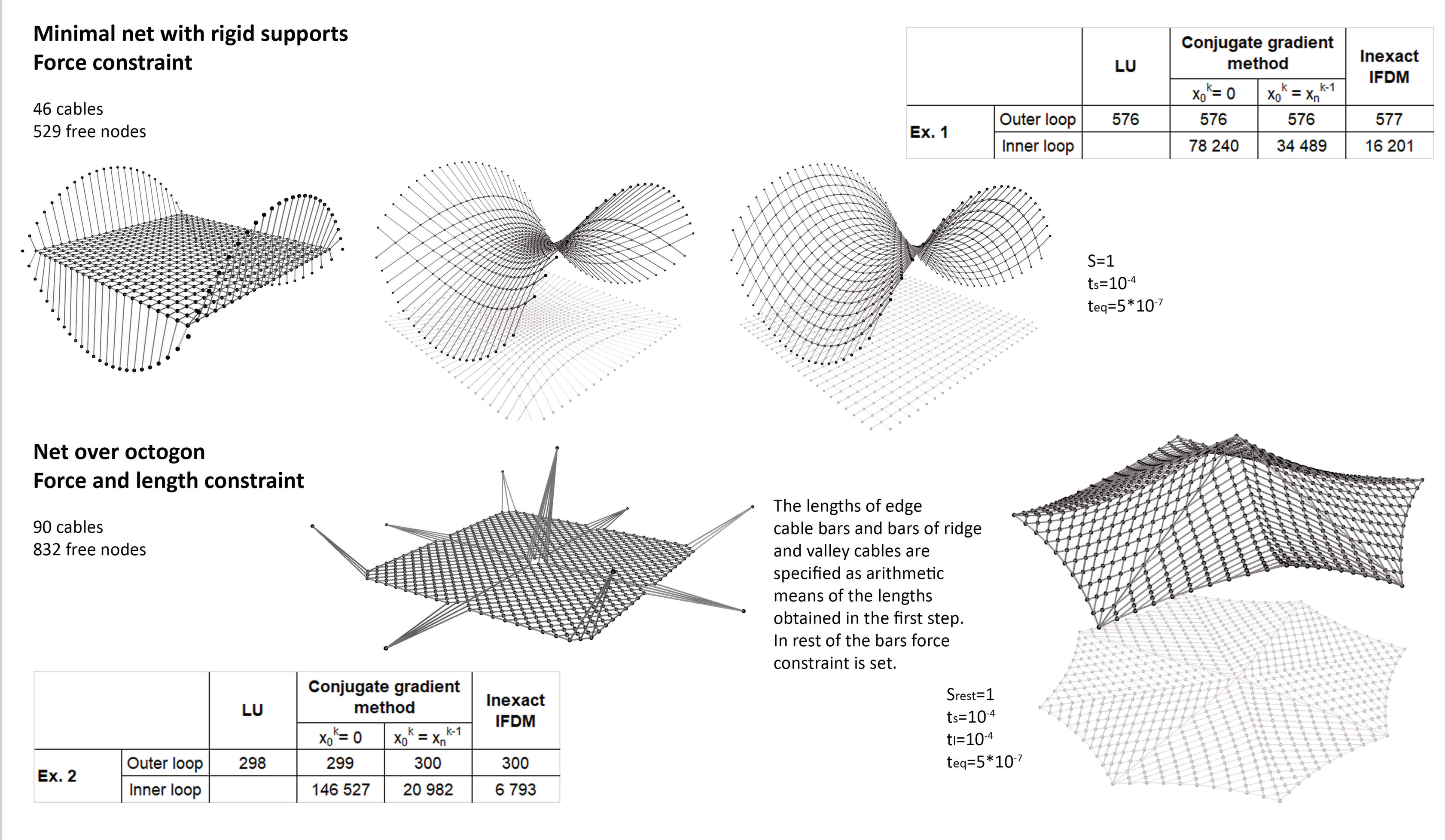


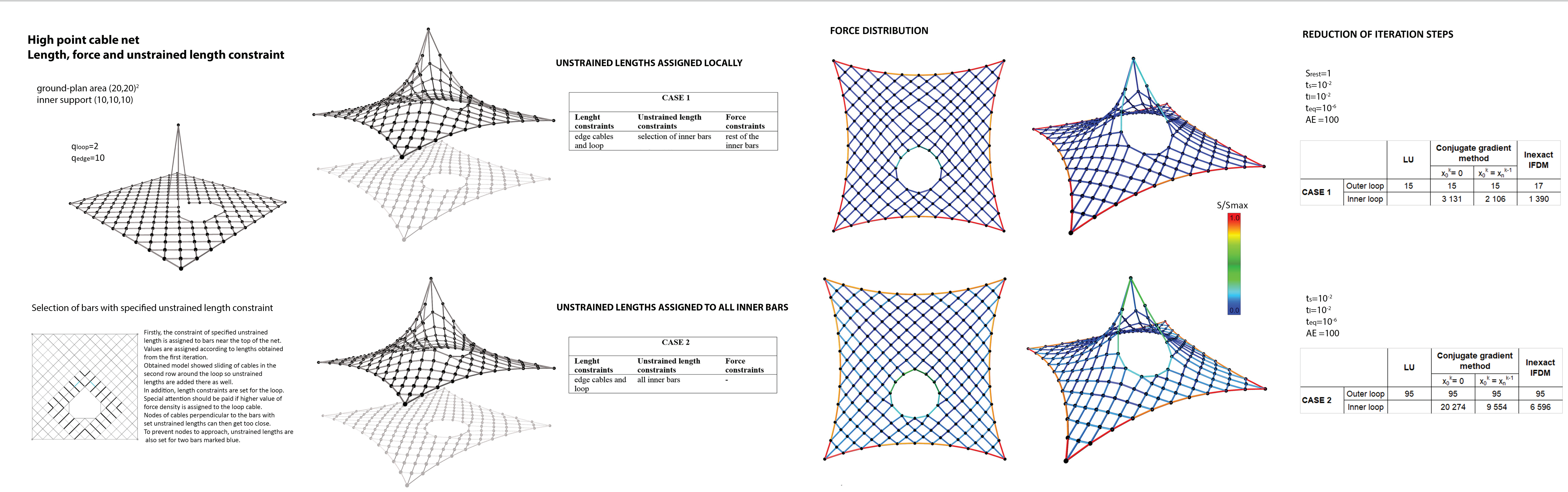
Figure 1:Flow chart of the Inexact Iterated FDM.



		LU	Conjugate gradient method		Inexact IFDM
			$x_0^k = 0$	$x_0^k = x_n^{k-1}$	
Ex. 1	Outer loop	576	576	576	577
	Inner loop		78 240	34 489	16 201

		LU	Conjugate gradient method		Inexact IFDM
			$x_0^k = 0$	$x_0^k = x_n^{k-1}$	
Ex. 2	Outer loop	298	299	300	300
	Inner loop		146 527	20 982	6 793

Figure 2: Saddle shaped example with force constraints and octagon shaped example with force and length constraints.



CASE 1		
Lenght constraints	Unstrained length constraints	Force constraints
edge cables and loop	selection of inner bars	rest of the inner bars

CASE 2		
Lenght constraints	Unstrained length constraints	Force constraints
edge cables and loop	all inner bars	-

		LU	Conjugate gradient method		Inexact IFDM
			$x_0^k = 0$	$x_0^k = x_n^{k-1}$	
CASE 1	Outer loop	15	15	15	17
	Inner loop		3 131	2 106	1 390

		LU	Conjugate gradient method		Inexact IFDM
			$x_0^k = 0$	$x_0^k = x_n^{k-1}$	
CASE 2	Outer loop	95	95	95	95
	Inner loop		20 274	9 554	6 596

Figure 3: Two approaches to obtain high point cable net with uniform force distribution, by assigning length, unstrained length or force constraints.

Future Work

The oncoming step in research development is conduction of time measurements and comparisons of results to nonlinear FDM. Further extension to membrane elements is expected. Described research is part of the project Novel, Efficient Iterative Procedure for the Structural Analysis that proposes new iterative method for solving systems of linear equations and obtained numerical models are intended to serve for testing of the proposed procedure in application on nonlinear systems of equations.

Acknowledgements

This work was fully supported by HRZZ under the project IP-2014-09-2899.

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